LIMITATION OF MOBILE HEAD CT SCANNER (CERETOM) IMAGE QUALITY IN A NEUROSURGERY CENTER

by

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Introduction: Computed tomography (CT) has become the preferred technique in the diagnostic toolkit for head and brain imaging and superior to Magnetic Resonance Imaging (MRI) for the assessment of head injury. Indications for head imaging includes head injury, acute stroke, subarachnoid haemorrhage etc. A more recent development in CT imaging has been the development of a mobile CT scanner which can be beneficial from clinical and economical point of views.

Objective: To compare the image quality of CT brain images produced by mobile head CT scanner, CereTom, to standard fixed CT scanner.

Methods: This was a single center retrospective study involving CT brain images of112 neurosurgical patients admitted to Hospital SultanahAminah Johor Bahrufrom December 2014 until March 2015. Hounsfield unit(HU) of all the selected images from CereTom were measured for: air, water and bone. Three observers (2 neurosurgeons and 1 radiologist) evaluated independently the CT brain images acquired on standard fixed CT scanner within 48 hours apart with theCereTom. Each images were evaluated for visualization of lesions, grey-white matter differentiation and streak artifacts at 3 different levels which were centrum semiovale, basal ganglia and middle cerebellar peduncles. Each evaluation was scored either 1 (poor), 2 (average) or 3 (good). The scores were sum up forming an ordinal reading of 3 to 9.

Results: Hounsfield unit (HU) for measured air, water and bone from CereTom were within the range of recommended by ACR. Evaluation of streak artifacts demonstrated scores of 8.54 (IQR 0.24) with fixed CT scanner versus 7.46 (IQR 1.16) for CereTom at centrum semiovale (z -5.67), 8.38 ± 1.12 versus 7.32 ± 1.63 at the basal ganglia and 8.21 ± 1.30 versus 6.97 ± 2.77 at the middle cerebellar peduncles. Comparison of grey-white matter differentiation showed scores of 8.27 ± 1.04 with fixed CT scanner versus 7.21 ± 1.41 for CereTom at centrum semiovale, 8.26 ± 1.07 versus 7.00 ± 1.47 at the basal ganglia and 8.38 ± 1.11 versus 6.74 ± 1.55 at the middle cerebellar peduncles. Evaluation for visualization of lesions showed scores of 8.86 (IQR 0.09) with fixed CT scanner compared to 8.21 (IQR 0.34) for CereTom at centrum semiovale (z -4.24), 8.93 (IQR 0) versus 8.18 (IQR 0.57) at the basal ganglia (z -5.32) and 8.79 (IQR 0.11) versus 8.06 (IQR 0.41) at the middle cerebellar peduncles (z -4.93). All the results were significant with p value < 0.01.

Conclusion: The results of this study showed there were significant differences in terms of image quality between the images produced by fixed standard CT scanner and CereTom with the latter being more inferior. However, Hounsfield unit (HU) of images produced by CereTom do fulfil the recommendation by ACR.

Dr Johari Siregar Adnan: Supervisor

Dr Noor Azman A. Rahman: Supervisor

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LIST OF ABBREVIATIONS

CT	Computed Tomography
X-ray CT	X-ray Computed Tomography
CAT	Computerized Axial Tomography
MRI	Magnetic Resonance Imaging
ART	Algebraic Reconstruction Technique
UCLA	University of California, Los Angeles
EBT	Electron Beam Tomography
DICOM	Digital Imaging and Communications in Medicine
PACS	Picture Archiving and Communication System
CTDI	Computed Tomography Dose Index
ALARA	As Low As Reasonably Achievable
HSAJB	Hospital Sultanah Aminah Johor Bahru
ACR	American College of Radiology
HU	Hounsfield unit
MREC	Medical Research and Ethics Committee

ABSTRAK

Tajuk: Penilaian Kualiti Imej yang dihasilkan oleh Pengimbas CT Mudah Alih (CereTom) di Pusat Rawatan Neurosurgeri.

Pengenalan: Computed tomography (CT) telah menjadi teknik pilihan dalam pengimejanotak. CT lebih baik daripada Magnetic Resonance Imaging (MRI) untuk penilaian kecederaan kepala. Penggunaan pengimejan otak termasuk kecederaan kepala, angin ahmar, pendarahan subaraknoid dan lain-lain.Salah satu perkembangan dalam pengimejan CT adalah pengimbas CT mudah alih yang boleh memberi manfaat dari segi klinikal dan ekonomi.

Objektif: Untuk menilai kualiti imej imbasan otak yang dihasilkan olehpengimbas CT mudah alih, CereTom, berbanding alat pengimbas CT tetap.

Kaedah: Ini adalah satu kajian retrospektif yang melibatkan imej CT otak bagi 112 pesakit neurosurgeri yang dimasukkan ke Hospital Sultanah Aminah Johor Bahru dari Disember 2014 hingga Mac 2015. Hounsfield unit (HU) bagi semua imej otak dari CereTomdiukur untuk udara, air dan tulang. Tiga pemerhati (2 pakar bedah neuro dan 1 ahli radiologi) menilai secara bebas imej otak CT daripada pengimbas CT tetap dan CereTom. Setiap imej telah dinilai untuk visualisasi luka, perbezaan jirim putih dan kelabuserta artifak coretan pada 3 tahap otak yang berbeza

iaitucentrum semiovale, basal ganglia dan middle cerebellar peduncles. Setiap penilaian diberikan markah samada 1 (buruk), 2 (purata) atau 3 (baik) membentuk bacaan ordinal daripada 3 hingga 9.

Keputusan: Unit Hounsfield (HU) untuk udara, air dan tulang yang diukur dari CereTom berada dalam julat yang disyorkan oleh ACR. Penilaian artifak coretan menunjukkan nilai8.54(IQR 0.24) berbanding 7.46 (IQR 1.16)untuk CereTom di tahap centrum semiovale (z -5.67),8.38± 1.12berbanding 7.32 ± 1.63 pada basal ganglia dan 8.21± 1.30 berbanding 6.97 ± 2.77 pada middle cerebellar peduncles. Perbandingan perbezaan jirim putih dan kelabumenunjukkan nilai 8.27± 1.04 berbanding 7.21± 1.41pada centrum semiovale, 8.26± 1.07 berbanding 7.00 ± 1.47 pada basal ganglia dan 8.38 ± 1.11 berbanding 6.74± 1.55 pada middle cerebellar peduncles. Penilaian visualisasi luka menunjukkan nilai 8.86 (IQR 0.09) dengan pengimbas CT tetap berbanding 8.21 (IQR 0.34) dengan CereTom di tahap centrum semiovale (z -4.24), 8.93 (IQR 0) berbanding 8.18(IQR 0.57) pada basal ganglia (z -5.32) dan 8.79 (IQR 0.11) berbanding 8.06 (IQR 0.41)pada middle cerebellar peduncles (z -4.93). Semua keputusan tersebut mempunyai nilai $p < 0.01$.

Kesimpulan: Hasil kajian menunjukkan terdapat perbezaan dari segi kualiti imej antara imej-imej yang dihasilkan oleh pengimbas CT tetap dan CereTom yang mana kualiti imej dari CereTom adalah lebih rendah. Walau bagaimanapun, unit Hounsfield (HU) dari imej otak yang dihasilkan oleh CereTom mematuhi piawaian yang telah disyorkan oleh ACR.

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ABSTRACT

Title: Evaluation of Image Quality produced by Portable Head CT Scanner (CereTom) in a Neurosurgery Center.

Introduction: Computed tomography (CT) has become the preferred technique in the diagnostic toolkit for head and brain imaging and superior to Magnetic Resonance Imaging (MRI) for the assessment of head injury. Indications for head imaging includes head injury, acute stroke, subarachnoid haemorrhage etc. A more recent development in CT imaging has been the development of a mobile CT scanner which can be beneficial from clinical and economical point of views.

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Conclusions: The results of this study showed there wassignificant difference in terms of image quality between the images produced by fixed standard CT scanner and CereTom with the latter being more inferior. However, Hounsfield unit (HU) of images produced by CereTom do fulfil the recommendation by ACR.

CHAPTER 1: INTRODUCTION

Computed tomography (CT) scan, also called X-ray computed tomography (X-ray CT) or computerized axial tomography scan (CAT scan), derives from computer-processed combinations of many X-ray images to produce cross-sectional (tomographic) images of specific areas from a scanned object. Medical imaging is the most common application of CT scan for diagnostic and therapeutic purposes. CT scan has become the most accessible diagnostic toolkit for head and brain imaging.

The use of CT in general has led to a major shift since its invention in the 1970s and 1980s. Development of CT imaging with funding from the recording company EMI led to a Noble prize in Physiology or Medicine in 1979 (Alexander et al. 2010). In emergency settings, CT scan is superior to Magnetic Resonance Imaging (MRI). Indication for head CT imaging includes head trauma, transient ischaemic attack, acute stroke, subarachnoid haemorrhage etc.

Usage of CT has increased greatly over the last two decades. An estimated 72 million CT scans were done in the United States in 2007 (Berrington et al. 2009). A more recent advancement in CT imaging has been the development of a mobile head CT scanner that can be beneficial from clinical and economical point of views.

Risks during transportation for imaging can be minimized if mobile head CT scanner is available for patients in critical care. The risks include compromise of monitoring devices, intubation tubes, intravenous lines, hypotension, hypoxia and increased intracranial pressure. Even in the setting of a well-trained transport team comprises of senior staffs, the adverse events still happened 15% of the time (Waydhas, 1999).

Avoiding transportation of patients requiring imaging has other added benefits as well. It reduces the amount of time required for imaging by abolishing transport time for patients and also serves to improve the utility of fixed CT scanner of the hospital by reducing work load of standard CT scanner (Masaryk et al. 2008). Hence, this will help into faster imaging for other non-critical care patient, thereby improving their quality of care.

The NeuroLogica CereTom CT scanner was introduced to the worldwide market in 2004. It is a portable CT scanner use primarily in neurological intensive care. It may also be used in operating theater to facilitate surgery or to provide a check for surgical outcomes. CereTom can be used to replace the need for transporting a patient to a fixed CT scanner in radiology department. A cost analysis done on the use of CereTom calculated a return on investment of 169% taking into consideration the cost of the machine, US$359,000 and the single operator needed to operate the machine (Masaryk et al. 2008).

CHAPTER 2: LITERATURE REVIEW

2.1: Origins of tomography

Italian radiologist, Allessandro Vallebona, developed a method to represent a single slice of the body on radiographic film in the early 1900’s which was later known as tomography. The method was based on simple principles of projective geometry: moving synchronously and in opposite directions of the X-ray tube and the film, which are connected together by a rod whose pivot point is the focus; the image created by the points in focal plane appears sharper, while the images of the other points annihilate as noise. This is only marginally effective, as blurring occurs.

Now known as conventional tomography, this method of acquiring tomographic images had advanced through the mid-twentieth century, producing sharper and clearer images with a greater ability to vary the thickness of cross-section being examined. All these have been made possible with the introduction of more complex, multidirectional devices that can move in more than one plane and perform more effective imaging.

Despite the increasing complexity of conventional tomography, it failed to produce satisfactory images of soft tissues. In the 1960s, research began into practical computational techniques for creating tomographic images with the availabilily of computers.

2.2: Mathematical theory

The mathematical theory behind computed tomographic reconstruction dates back to 1917 where Austrian mathematician Johann Radon invented Radon Transform. He proved that a function could be reconstructed from an infinite set of its projections through careful mathematical calculations.

In 1937, a Polish mathematician, Stefan Kaczmarz, developed a technique to find solution to a large system of linear algebraic equations. This led to the foundation of a reconstruction method called Algebraic Reconstruction Technique (ART) which was later implemented by Sir Godfrey Hounsfield as the image reconstruction mechanism in his famous invention, the first commercial CT scanner.

In 1959, William Oldendorf, a UCLA neurologist at the West Los Angeles Veterans Administration hospital, was caught with an idea for 'scanning a head through a transmitted beam of x-rays, and being able to reconstruct the radiodensity patterns of a plane through the head'. He had this idea after watching how a device built to reject frostbitten fruit by detecting dehydrated portions works. In 1961, he successfully built a prototype in which he arranged the X-ray source and a mechanically coupled detector rotated around the object to be scan. In his landmark paper published in 1961, he described the basic concept of his invention which was later adopted by Allan McLeod Cormack to develop the mathematics behind computerized tomography.

Tomography has been one of the pillars of radiologic diagnostic tools until the late 1970s, when the availability of computers and transverse axial scanning method led CT to be the preferred modality of obtaining tomographic images. Transverse axial scanning was attributed largely to the hardwork of Sir Godfrey Hounsfield and Allan McLeod Cormack based upon the use of the Radon Transform.

2.3: Types of machines

Spinning tube, commonly called spiral CT or helical CT is an imaging technique in which an entire X-ray tube is spun around the central axis of the area being scanned. These are the dominant type of scanners on the market because they have been manufactured longer and offer lower cost of production and purchase. The main limitation of this type is the bulk and inertia of the equipment (X-ray tube assembly and detector array on the opposite side of the circle) which limits the speed at which the equipment can spin.

Electron beam tomography (EBT) is a specific form of CT in which a large enough X-ray tube is constructed so that only the path of the electrons, travelling between the cathode and anode of the x-ray tube, are spun using deflection coils. This type had a major advantage since sweep speeds can be much faster, allowing for less blurry imaging of moving structures such as the heart. Fewer scanners of this design have been produced when compared with spinning tube types, mainly due to the higher cost. Only one manufacturer (Imatron, later acquired by General Electric) ever produced scanners of this design. Production ceased in early 2006.

2.4: Commercial scanners

The first commercially viable CT scanner was invented by Sir Godfrey Hounsfield in Hayes, United Kingdom, at EMI Central Research Laboratories using X-rays. Hounsfield conceived his idea in 1967. The first EMI-Scanner was installed in Atkinson Morley Hospital in Wimbledon, England, and the first patient to undergo brain-scan was done on 1st October 1971. It was publicly announced in 1972.

The original 1971 prototype took 160 parallel readings through 180 angles, each 1° apart, with each scan taking a little over 5 minutes. The images from these scans took 2.5 hours to be processed by algebraic reconstruction technique (ART) on a large computer. The scanner had a single photomultiplier detector and operated on the Translate/Rotate principle. The images were relatively low resolution, being composed of a matrix of only 80 x 80 pixels. Allan McLeod Cormack of Tufts University in Massachusetts independently invented a similar process, and both Sir Hounsfield and Cormack shared the 1979 Nobel Prize in Medicine. In 1981, Sir Godfrey Hounsfield received a knighthood for his work.

Since the first CT scanner, CT technology has vastly improved. Improvements in speed, slice count and image quality has been the major focus for imaging. Scanners now produce images much faster and with higher resolution enabling doctors to diagnose patients more accurately and perform medical procedures with greater precision. Current CT scanners can produce images with up to 1024 x 1024 matrix, acquiring data for a slice in less than 0.3 seconds. Development continued through 1990s, with the introduction of spiral (continuous) scanning and the development of multi-slice scanners. In the early years of the 21st century, development of CT scanner technology continued through particularly with multi-slice scanners with high-end scanners were offering up to 320 slices, dual source and dual-energy x-ray sources.

In the late 1990s, CT scanners broke into two major groups: ‘Fixed CT’ and ‘Portable CT’. ‘Fixed CT scanners’ are large, require a dedicated power supply, electrical closet, a separate workstation room and a large lead lined room. ‘Portable CT scanners’ are lightweight, small and mounted on wheels with built-in lead shielding and run off on batteries or standard wall power.

Several portable CT scanners are currently available for clinical imaging which includes the CereTom (Neurologica), the OTOscan (Neurologica), the xCAT ENT (Xoran Technologies), and the Tomoscan (Philips Medical Systems). The OTOscan is a multisection CT scanner for imaging in ear, and throat settings to assess bone and soft tissue of the head. xCAT ENT is a conebeam CT scanner which can be used for intraoperative canning of cranial bones and sinuses. Tomoscan consists of multisection detectors and a detachable table which can performs a full-body scanning or the gantry can be used without the table for head scan.

2.5: CereTom (NeuroLogica)

CereTom is a compact, portable, battery and mains powered multi-slice CT scanner designed for scanning anatomy that can be imaged in the 25cm field, primarily the head and neck. It has a 32cm aperture for the patient's head to be positioned. The system comprises two units which is the scanner and the workstation.

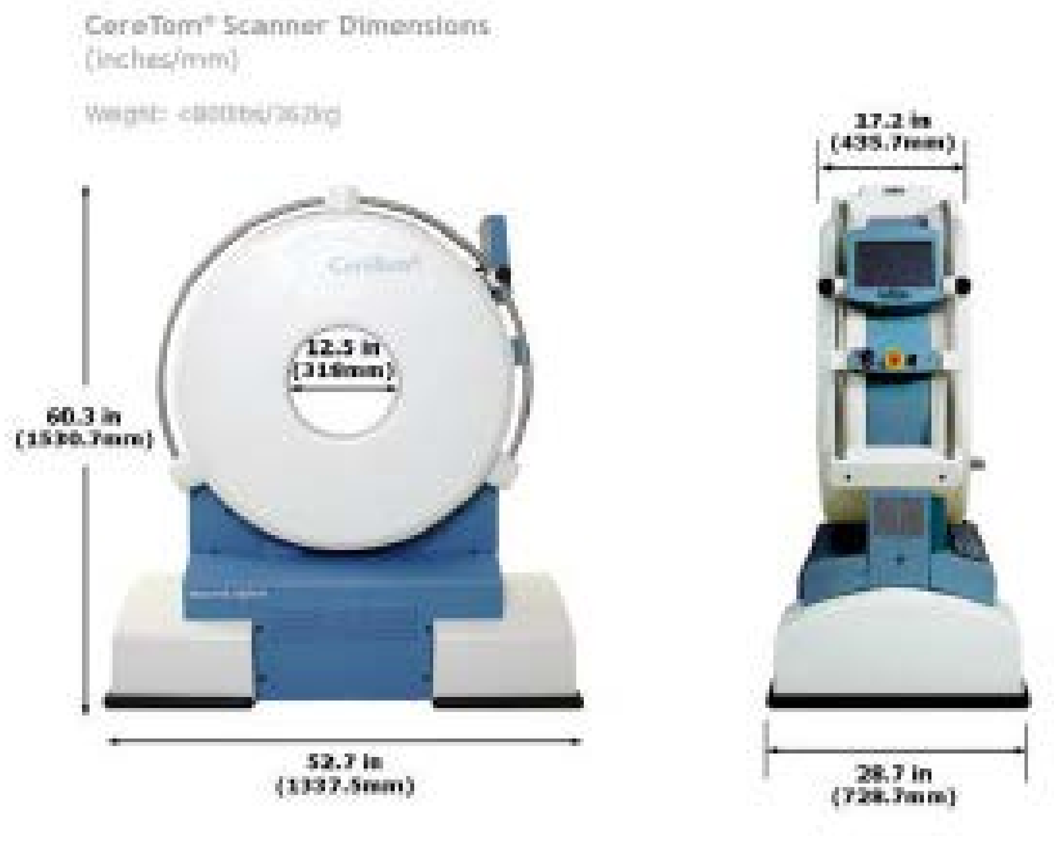

Figure 1: CereTom scanner (Source: NeuroLogica CereTom ® Portable CT scanner brochure). CereTom scanner height measures 153cm with width of 134cm and length 73cm. It weights approximately 362.9kg.

2.5.1: Scanning capabilities

CereTom is an eight-slice CT scanner with complete self-contained lead shielding. The detector can sample eight data channels of 1.25mm thickness and these channels can be combined to produce thicker slices. The scanner can run in axial (sequential) mode or helical (spiral) mode. Axial mode can be used to produce slices within one10mm region or many slices from neighbouring regions. It can produces images of 1.25, 2.5, 5.0, 10.0mm slice thickness.

CereTom is able to perform standard non-contrasted CT scans, contrast-enhanced CT scans, CT angiography scans and CT perfusion scans.

2.5.2: Workstation

There is a small control panel mounted on the side of the gantry which is used to move the scanner for scanning. In an emergency situation, a scan protocol can be selected to initiate scanning from this panel. Otherwise, the main control interface and image review is from a laptop imaging computer with 17” high resolution monitor that is separate from the gantry.

The workstation is used to record details of patient, the study and the examination series. Communication between the workstation and the scanner can be a wireless connection or a cable connection is also available. Scan protocols or set up can be done from the workstation and transferred to the scanner. When scanning is complete, the images can be downloaded to the workstation where they can be reviewed. The workstation can export images as DICOM compatible files and integrates with all PACS.

Figure 2: Control panel mounted on the side of the gantry

Figure 3: Laptop computer with 17” high resolution monitor that is separate from the gantry. It is the main workstation with wireless connection.

2.5.3: Mobility

CereTom is designed to be easily transported between scan locations within the hospital. It moved on four castors and during scanning, the unit can be lowered onto caterpillar tracks that provides a stable base for scanning and allow the motion of the scanner to be controlled in one direction along the scan axis.

2.5.4: Scan board

CereTom is supplied with a universal scan board as standard, which is made from radiolucent carbon fiber material. The scan board is compatible with almost all bed types. Should a hospital or site have only one bed type, then custom scan board is available. For scanning, the scan board attaches to the head of the bed and patient being slides up which allows for patient to be scanned in their own bed.

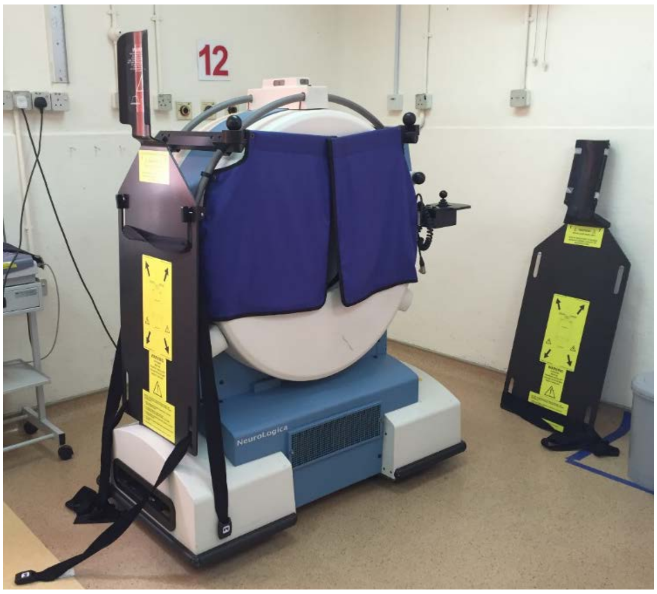

Figure 4: The universal scan board for CereTom which can be attached to the gantry for easy storage and mobility

2.6: Advantages and disadvantages of portable CT scanner

Severity of patient illness was the common reason for using portable CT scanning as opposed to scanning on a fixed CT scanner (McCunn et al. 2000). Those with extracorporeal support and those with cardiovascular, respiratory or neurological instability were commonly too ill to transport. If portable CT scanner was not available, most treating doctors would ordered a fixed CT scan and the patient was transported to the imaging department regardless of medical condition. Portable CT scan offered an alternative and potentially safer means of obtaining the required diagnostic imaging.

Transportation of unstable neurosurgical patients involve risks that can lead to further deterioration and the possibility of secondary brain insult. Complications occurred during transportation to the imaging department for fixed head CT scanning were compared with complications during portable CT scanning and it was concluded that portable CT scanning in the critical care unit is safe and reduces the risk of physiological deterioration and other potential problems linked to transport of the patient (Gunnarsson et al. 2000). There is 13% morbidity when transporting critically ill patient outside of the intensive care unit and the incidence of adverse events that happens during transportation for CT scanning could be as high as 71% (Masaryk et al. 2008). In addition, the time patients spend outside the controlled environment of the critical care unit is minimized and the staff workload is decreased.

Usage of portable CT in a critical care unit setting had additional diagnostic gain and therapeutic consequences. Patients who were unstable or critically ill and considered ‘not transportable’ were examined directly in the patient room while all other examinations can be performed in a special interventional suite directly in the critical care unit. For over half of the patients, portable CT scan resulted in a change in patient management and it was considered that all patients benefited from portable CT scanning (Teichgraber et al. 2003). Doing portable CT scanning directly in the critical care unit allows immediate and minimally invasive therapeutic interventions and provides improved monitoring of the patient.

The costs of performing a CT examination included fixed costs (machine costs, service contract etc) and variable costs (which varies in proportion to the number of examinations performed) such as supplies, maintenance and salaries. The cost of portable CT scanner was approximately 50% higher than fixed CT scanner (Mayo-Smith et al. 2003) where indirect costs such as administration costs were also addressed. Another study showed that usage of portable CT scanner in the critical care unit is feasible and cost effective and that the use of a portable scanner can provide a full return on investment within one year (Masaryk et al. 2008). However, the usage of portable CT scanner depends on a number of factors including image quality, examination costs and value to the patient. Also the utility depends on severity of the illness of the patient.

Waiting time for imaging using fixed and portable CT scanners for stroke patients in emergency department can be reduced to allow faster implementation of appropriate treatment. Thus the use of portable CT scanner facilitated more rapid assessment of acute stroke patients and would increase the number of patients who can receive thrombolytic therapy.

Image quality and clinical content of portable abdominal CT scanning was compared to those from fixed CT scanner and it was found that the quality scores for portable CT scans were consistently lower than those for fixed CT scans (both with and without contrast medium). Even though it was concluded that image quality was inferior to fixed CT scanner, portable abdominal CT scan does provide important diagnostic information without requiring patient being transport outside from the critical care unit (Maher et al. 2004).

2.7: Scanning protocol

2.7.1: Scanning protocol of fixed CT scanner (SOMATOM Volume Zoom)

Rotation time	:	0.75 or 1 second
Slice thickness	:	1 mm for the base of skull
		2.5mm for the cerebrum
Number of slices per scan	:	4
Table feed / rotation	:	2.7 or 3.5 mm
kV / mAs	:	120 / 260 to 350
Reconstructed scan width	:	4mm for the base of skull
		7 or 8mm for the cerebrum

This protocol is the standard operating protocol for all non-contrast CT brain (axial scan) in Hospital Sultanah Aminah Johor Bahru.

2.7.2: Scanning protocol of portable CT scanner (CereTom) for non-contrast CT brain (Axial scan)

Rotation time	:	2 seconds
Slice thickness	:	2.5 mm
Number of slices per scan	:	4
Typical scan range	:	25 cm
kV / mA	:	140 / 7
Reconstructed scan width	:	5mm

2.8: Radiation

The scanner provides protective lead curtains so that the radiation is well within ALARA (as low as reasonably achievable) standards. The specifications for CereTom states that ‘at a distance of 2 meters from the isocenter, an operator can perform over 26 scans per day, for 250 days per year without any additional lead protection. Therefore, the dose for the operator conducting the scan is well within the acceptable range when proper precautions are taken.

2.9: Problem statement

To date, there has been no local study done to evaluate the image quality produced by mobile head CT scanner. With this study, it can help us in determining the quality of images produced. If it is proven to be as good as fixed CT scanner, then we can suggest for the usage of mobile head CT scanner in the future given the many advantages that it has. This study can also serve as a guidance for future studies.

CHAPTER 3: OVERVIEW OF MANAGEMENT OF PATIENT ADMITTED TO NEUROSURGERY CENTER, HOSPITAL SULTANAH AMINAH JOHOR BAHRU

3.1: Referral and admission

The department of Neurosurgery, Hospital Sultanah Aminah Johor Bahru (HSAJB), generally is the sole provider of neurosurgical service in the state of Johor in south Malaysia. The department of Neurosurgery, HSAJB received referrals from all the hospitals within the 10 districts across Johor state. Generally, HSAJB received and manage about

Patients of all ages from hospitals with available CT scanner facility will have the initial CT brain done in their respective hospital, whereas for those without CT scanner facility will be transferred to the nearest hospital with facility for imaging to be done. Following the imaging, patients will be referred to HSAJB for further management.

3.2 Treatment protocol

For all patients being transferred or admitted to HSAJB will be reassessed by Neurosurgery team. Patients whom required surgery will undergo surgical intervention and admitted to intensive care unit. Patients who do not require any surgical intervention during admission will be closely monitored either in the ward or high dependency unit based on severity of illness.

Patients under close monitoring will have a repeat CT brain within 12 to 48 hours depending on the conditions of each individual patient. Subsequent management of each patient will be carried out based on their clinical condition and imaging findings.

3.3 Brain scanning procedure

Since the availability of CereTom in HSAJB in 2011, repeat CT brain has been done using CereTom. The setup of Neurosurgery ward including the intensive care unit in HSAJB is difficult for the mobilization of CereTom to patient for imaging. Hence, a designated area within 50 meters has been setup to place the CereTom for the purpose of doing CT brain for patients. With this setup, patient will be transferred from bed to CereTom for scanning, but the distance is significantly shorter and total duration for imaging has been remarkably reduce.

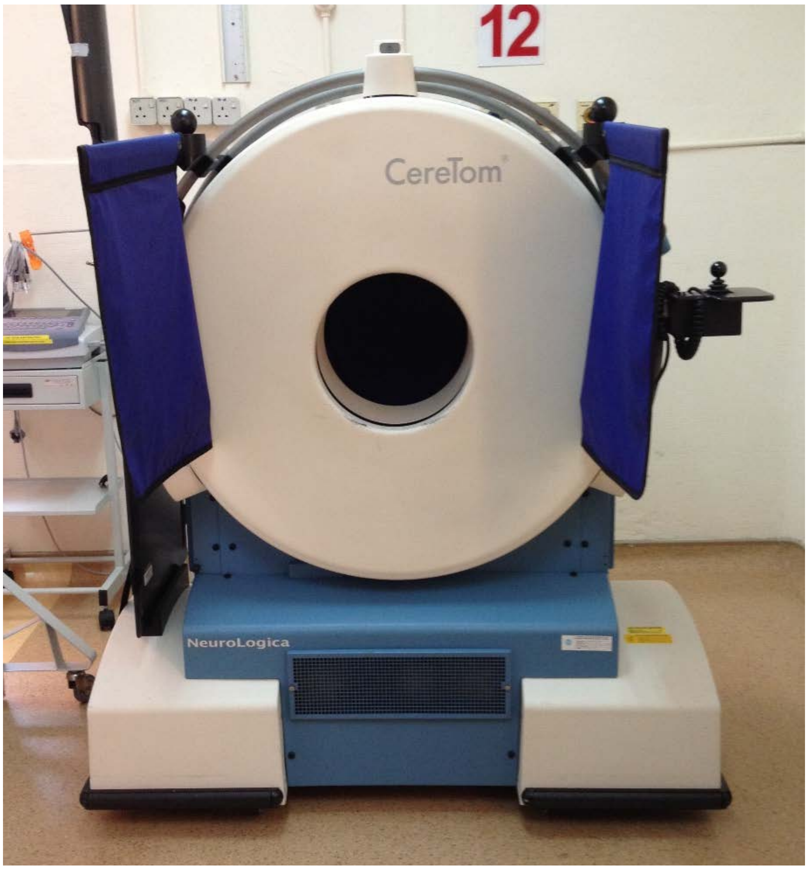

Figure 5: The CereTom machine in Hospital Sultanah Aminah, Johor Bahru

CHAPTER 4: OBJECTIVES OF STUDY

4.1 General objective

To evaluate the quality of CT brain images produced by portable head CT scanner, CereTom, for patients admitted to Neurosurgery center, HSAJB.

4.2 Specific objectives

1. To measure the CT number (Hounsfield unit) for air, water and bone in the images produced by portable CT scanner (CereTom) and compared to the CT number recommended by American College of Radiology (ACR).
2. To compare image quality evaluation scores for the presence of streak artifacts at the level of centrum semiovale, basal ganglia and middle cerebellar peduncle between images produced by fixed CT scanner and portable CT scanner (CereTom).
3. To compare image quality evaluation scores for grey-white matter differentiation at the level of centrum semiovale, basal ganglia and middle cerebellar peduncle between images produced by fixed CT scanner and portable CT scanner (CereTom).
4. To compare image quality evaluation scores for visualization of lesions at the level of centrum semiovale, basal ganglia and middle cerebellar peduncle between images produced by fixed CT scanner and portable CT scanner (CereTom).

CHAPTER 5: METHODOLOGY

5.1 Study design

This was a single center retrospective study.

5.2 Study population

The study population consisted of trauma and non-trauma patients admitted to Neurosurgery center, HSAJB from December 2014 until March 2015 with intracranial pathology during admission. The intracranial pathology can be extradural haemorrhage, subdural haemorrhage, subarachnoid haemorrhage, intraparenchymal haemorrhage, foreign body or others.

5.3 Subjects

5.3.1 Inclusion criteria

1. CT brain images taken from traumatic and non-traumatic patients of all age group and sex.
2. CT brain images acquired on portable CT scanner (CereTom) and fixed CT scanner within 48 hours apart
3. Intracranial pathology seen within the brain images. The intracranial pathology can be extradural haemorrhage, subdural haemorrhage, subarachnoid haemorrhage, intraparenchymal haemorrhage, foreign body or others.
4. No surgical intervention has been done in between the imaging.

5.3.2 Exclusion criteria

1. Images were done more than 48 hours apart.
2. Prominent artifacts from external devices preventing a clear assessment of portable CT scanner (CereTom) images, fixed CT images or both.
3. Surgical intervention has been carried out in between the imaging.

5.4 Alternative hypothesis

1. There were difference in the CT number (Hounsfield unit) accuracy for air, water and bone at the level of middle cerebellar peduncles produced by portable CT scanner (CereTom) compared to the recommended value by American College of Radiology (ACR).
2. There were difference of image quality evaluation scores for the presence of streak artifacts at the levels of centrum semiovale, basal ganglia and middle cerebellar peduncles for images produced by fixed CT scanner compared to portable CT scanner (CereTom).
3. There were difference of image quality evaluation scores for grey-white matter differentiation at the levels of centrum semiovale, basal ganglia and middle cerebellar peduncles for images produced by fixed CT scanner compared to portable CT scanner (CereTom).
4. There were difference of image quality evaluation scores for visualization of lesions at the levels of centrum semiovale, basal ganglia and middle cerebellar peduncles for images produced by fixed CT scanner compared to portable CT scanner (CereTom).

5.5 Methods

5.5.1 Collection of sample

Patient registry into the admission record was screened through together with the record book for portable CT scanner (CereTom) imaging. A list of patient names admitted to Neurosurgery ward, HSAJB from 1st December 2014 until 31st March 2015 was first generated from the admission record. Another list of patient names with the date of CT brain imaging done using portable CT scanner (CereTom) from 1st December 2014 until 3rd April 2015 was generated.

The two lists of names were compared. Only the names that appeared in both lists consisted of admission date and portable CT scanner (CereTom) imaging date which were not more than 3 days apart will be selected with no sampling done.

The images were retrieved from patient case notes in Neurosurgery Clinic, HSAJB where they were stored together. The date and timing for each imaging films were checked again to ensure that they were not done more than 48 hours apart.

A final list of 112 pairs of imaging films were then obtained.

5.5.2 Data analysis

i. CT number (Hounsfield unit, HU) of all the selected images from portable CT scanner (CereTom) were measured for: air, water and bone at the level of middle cerebellar peduncles (defined as the image in which pons and prepontine cistern were visualized) via the workstation of CereTom. The mean of measured value were compared to the CT number accuracy recommended by American College of Radiology (ACR).

Material	Recommended HU
Air	Between -1005 and -970
Water	Between -7 and +7
Bone	Between 850 and 970

The CT number accuracy recommended by ACR was acknowledge to produce a good quality CT brain.

ii. CT number (Hounsfield unit, HU) of grey and white matter were measured for images from portable CT scanner (CereTom) and fixed CT scanner at the level of centrum semiovale, defined as the image 5mm above the lateral ventricular system

iii. 2 neurosurgeons with more than 5 years' experience and 1 radiologist independently evaluated the CT brain images done on both the fixed CT scanner and CereTom for each patient.

a. All the images were evaluated at 3 different levels defined on axial imaging: